ARC JET COMPLEX

The Ames Arc Jet Complex has a rich heritage of over 40 years in Thermal Protection System (TPS) development for every NASA Space Transportation and Planetary program, including Apollo, Space Shuttle, Viking, Pioneer-Venus, Galileo, Mars Pathfinder, Stardust, NASP, X-33, X-34, SHARP-B1 and B2, X-37 and Mars Exploration Rovers. With this early TPS history came a long heritage in the development of the arc jet facilities. These are used to simulate the aerodynamic heating that occurs on the nose cap, wing leading edges and on other areas of the spacecraft requiring thermal protection. TPS samples have been run in the arc jets from a few minutes to over an hour, from one exposure to multiple exposures of the same sample, in order to understand the TPS materials' response to a hot gas flow environment (representative of real hyperthermal environments experienced in flight).

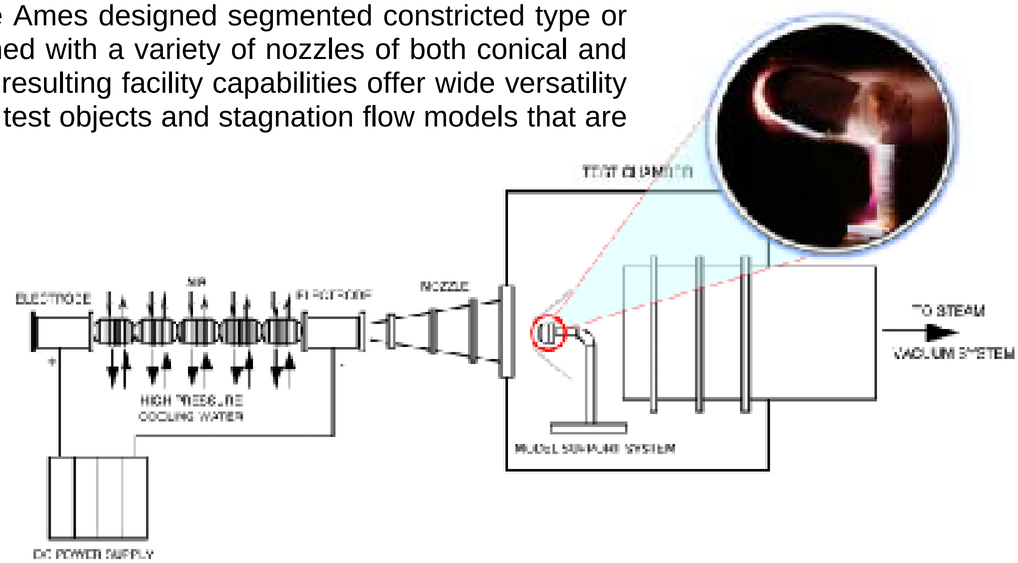
The Ames Arc Jet Complex is a key enabler for customers involved in the three major areas of TPS development: selection, validation, and qualification. The arc jet data are critical for validating TPS thermal models, heat shield designs and repairs, and ultimately for flight qualification.

SUMMARY DESCRIPTION OF THE TEST COMPLEX

The Ames Arc Jet Complex has seven available test bays located in two separate laboratory buildings. At the present time, four bays contain Arc Jet units of differing configurations that are serviced by common facility support equipment. These are the Aerodynamic Heating Facility (AHF) and Turbulent Flow Duct (2x9) in Building 234 and the Panel Test Facility (PTF) and the Interactive Heating Facility (IHF) in Building 238. The support equipment includes two D.C. power supplies, a steam ejector driven vacuum system, a water-cooling system, high-pressure gas systems, data acquisition system, and other auxiliary systems.

The large magnitude and capacity of these systems makes the Ames Arc Jet Complex unique in the world. The largest power supply can deliver 75 MW for a 30 minute duration or 150 MW for a 15 second duration. This power capacity, in combination with a high-volume 5-stage steam ejector vacuum-pumping system, enables facility operations to match high-altitude atmospheric flight conditions with relatively large size samples.

The arc heaters are of either the Ames designed segmented constricted type or the Hüels design. When combined with a variety of nozzles of both conical and semielliptical cross sections, the resulting facility capabilities offer wide versatility for testing both large flat-surface test objects and stagnation flow models that are fully immersed in the test stream.

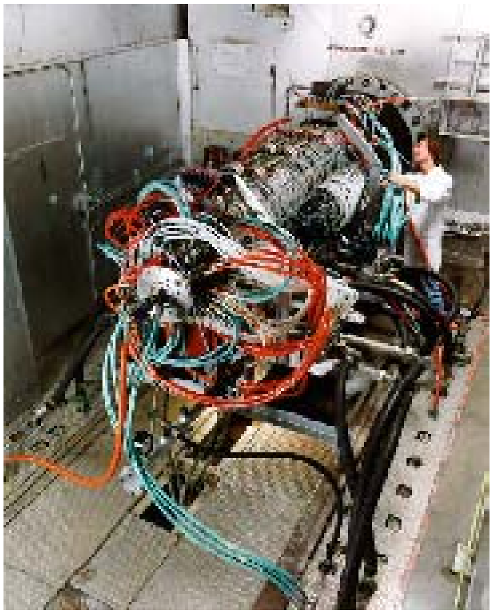


AERODYNAMIC HEATING FACILITY (AHF)

The AHF can operate with either a 20-MW constricted arc heater or a Hüels arc heater. The constricted heater operates at pressures from 1 to 9 atm and enthalpy levels from 1 to 33 MJ/kg (500 to 14000 Btu/lb), while the Hüels heater operates at pressure from 1 to 40 atm and enthalpies from 3.5 to 9.5 MJ/kg (1500 to 4500 Btu/lb). Either heater can be coupled with a family of conical nozzles with exit diameters ranging from 305 to 914 mm (12 to 36 in). A large add-air mixing plenum allows for very low enthalpies for ascent heating simulations. A fully programmable model insertion system independently controls five test samples during a single run.

Testing features include:

- Air or Nitrogen gases
- 20-MW Ames-designed constrictor arc heater or 20 MW Hüels arc heater
- Nozzles from 305mm (12 in) minimum to 914mm (36 in) maximum
- Samples sizes up to 203mm (8”) diameter or 660 by 660 mm (26” by 26”) wedge
- Surface or stagnation pressures from 0.005 to 0.3 (dependent on the arc heater and nozzle, see Table)
- Heat fluxes from less than 1 on a wedge, to over 3000 kW/m^2 on a 102mm dia hemisphere
- 5-arm fully programmable model insertion system
  - Nearly-vertical model insertion as well as transverse motion
  - Streamwise adjustment of model position
  - Fully water cooled design
  - Hydraulic motion controllers give reliable feedback control, programmable motion and digital communication
  - Programmable/variable insertion time, dwell time on centerline, retraction time, and carriage traverse time.



INTERACTION HEATING FACILITY (IHF)

The IHF is equipped with a 60-MW constricted heater that operates at pressures from 1 to 9 atm and enthalpy levels from 7 to 47 MJ/kg (3000 to 20000 Btu/lb). The facility is designed to operate with interchangeable conical nozzles with exit diameters ranging from 152 mm (6") to 1 m (41"). When the heater is coupled with the semielliptical nozzle, the test stream is suitable for testing flat panels of up to 610 x 610mm (24" by 24") in simulated hypersonic boundary layer flow environments.

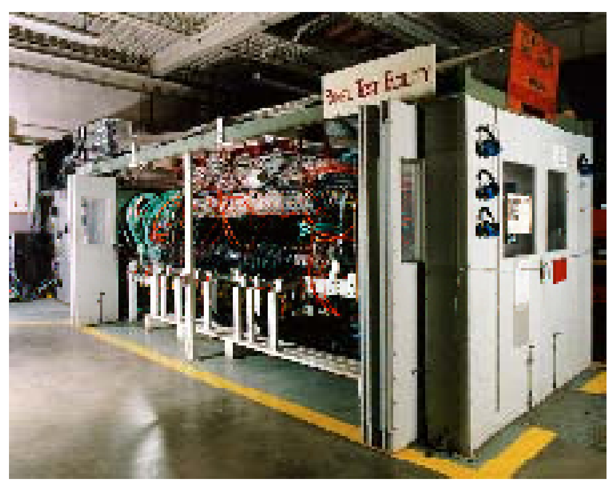
Testing features include:

- 60-MW Ames-designed constrictor arc heater
- Nozzle exit sizes from 152mm to > 1m (6" to 41")
- Stagnation, free jet wedge, or flat panel with semielliptic nozzle
- Stagnation pressures from 0.01 to over 1 atm
- Heat fluxes from 5 to >6000 kW/m^2
- Enthalpies from 7 to 47 MJ/kg (3000 to 20,000 Btu/lb)
- Power supply capable of delivering 75 MW for 30 minutes or 150 MW for a 15 second duration

PANEL TEST FACILITY (PTF)

The PTF facility operates with a 20-MW constricted heater that is coupled with a semielliptical nozzle. The heater operates at pressures from 1 to 9 atm and enthalpy levels from 7 to 35 MJ/kg (3000 to 15000 Btu/lb). The test stream generated is suitable for the simulation of boundary layer heating environments on flat panel samples of approximately 355 by 355mm (14" by 14"). However, it is possible to test sample sizes of 406 by 406mm (16" by 16").

The testing features include:



- 20-MW Ames-designed constrictor arc heater
- Semielliptic nozzle
- Test samples up to 355 by 355 mm (14" by 14")
- –4 deg to +8 deg inclinations of the surface of the test sample
- Run durations up to 30 minutes possible
- Cold wall (fully catalytic) heat flux from 6 to 340 kW/m^2 (0.5 to 30 Btu/ft^{2}s)
- Surface pressures from 66 to 4700 Pa (.0006 to .05 atm)

TURBULENT FLOW DUCT

Turbulent Flow Duct (2x9) is a supersonic duct used to study highly active, turbulent, two-dimensional fluid flows over a flat surface. The duct is rectangular and can accommodate models 203mm wide by up to 508mm (8” to 20”) of any desired depth. The duct operates at surface pressures from 0.02 to 0.15 atm and of shear stresses from 5 to 70 kg/m^2. A Hüels arc heater operating at enthalpy levels from 3 to 9 MJ/kg produces the flow.

Testing features include:

- Air or nitrogen gases
- Linde (Hüels) free-length arc heater (12-MW)
- Test samples of 203mm high by 508mm long (8” by 20”)
- Surface pressures from 0.02 to 0.15 atm
- Cold wall heat fluxes from 20 to 700 kW/m^2 (2 to 60 Btu/ft^2-s)
- Enthalpy range from 3 to 9 MJ/kg (1300 to 4000 Btu/lb)

Facility	Gas	Input Power (MW)	Type of Test Article	Nozzle Exit (inches)	Mach Number	Max Sample Size (inches)	Shear Stress (lb/ft^2)	Bulk Enthalpy (Btu/lb)	Surface Pressure (atm)	Convective Heating Rates (Btu/ft^2-s)
Aerodynamic Heating	Air N_2	20	Stag Pt. Wedge	Conical 12, 18, 24, 36 ∅	4-12	8 ∅ 26 x 26	< 2	500 to 14,000	.005-.125 .001	20-225 .05-22
Aerodynamic with Hüels	Air N_2	20	Stag Pt. Wedge	Conical 12, 18, 24, 36	4-12	8 Ø 26 x 26	< 2	1500 to 4500	.02 to 0.3	20 - 225
Interactive Heating Facility	Air	60+	Stag Pt. Wedge Flat Plate	Conical 6,13,21,30,41 Semielliptical 8 x 32	< 7.5 5.5	18 ∅ 24 x 24	< 2	3000-20,000	.010-1.2 .0001-.02	50-660 0.5-45
Panel Test Facility	Air	20	Flat plate	Semielliptical 4 x 17	5.5	16 x 16	< 2	3000-15,000	.0006-.05	0.5-30
Turbulent Flow Duct (2x9)	Air N_2	12	Flat plate	2 x 9	3.5	8 x 10 8 x 20	1-15	1300-4000	0.02-.15	2 – 60

Table 1 Arc Jet capabilities at Ames Research Center (US customary units)

Heating rate is a cold wall, fully catalytic value on a 4-inch diameter hemisphere.

Facility	Gas	Input Power (MW)	Type of Test Article	Nozzle Exit (mm)	Mach Number	Max Sample Size (mm)	Shear Stress (kg/m^2)	Bulk Enthalpy (MJ/kg)	Surface Pressure (kPa)	Convective Heating Rates (kW/m^2)
Aerodynamic Heating	Air N_2	20	Stag Pt. Wedge	Conical A, B, C, D ∅	4-12	2 0 3 ∅ 660 x 660	< 5	1 to 32.6	.5 – 12.7 0.1	227 - 2555 0.6 - 250
Aerodynamic with Linde	Air N_2	20	Stag Pt. Wedge	Conical A, B, C, D ∅	4-12	2 0 3 ∅ 660 x 660	< 5	3.5 to 10.5	2 to 30	227 - 2555
Interactive Heating Facility	Air	60+	Stag Pt. Wedge Flat Plate	Conical E, F, G, H, I Semielliptical 203 x 813	< 7.5 5.5	4 5 7 ∅ 610 x 610	< 5	7 to 46.5	1 – 121.6 0.01 - 2	568 - 7490 5.7 – 511
Panel Test Facility	Air	20	Flat plate	Semielliptical 102 x 432	5.5	406 x 406	< 5	7 to 35	.06 – 5.1	5.7 – 341
Turbulent Flow Duct (2x9)	Air N_2	12	Flat plate	51 x 229	3.5	203 x 254 203 x 508	5-73	3 to 9.3	2 – 15.2	23 - 681

Table 2 Arc Jet Complex capabilities (SI units)

Heating rate is a cold wall, fully catalytic value on a 102-mm diameter hemisphere

Conical A = 305 mm	B = 457 mm	C = 610 mm
D = 914 mm	E = 152 mm	F = 330 mm
G = 533 mm	H = 762 mm	I = 1041 mm

AMES ARC JETS: VERSATILE, ACCURATE, EFFICIENT, COMMITTED

Ames Research Center Arc Jets focuses on organizations that need to completely, accurately and efficiently test new Thermal Protection System concepts that use innovative materials and/or new design ideas.

We provide a variety of hyperthermal environments, encompassing heat shields and heat tolerance for ascent, entry to Earth or other planetary atmospheres, and hypersonic cruise regimes.

Our goal: seamless integration of your material characterization, model design, pretest planning and testing needs.

Unlike the alternative test environments, Ames Arc Jets have a comprehensive array of adaptable world-class test hardware. When combined with our staff's extensive expertise and the wide range of test experiences, we offer a unique set of test possibilities.

Full details can be found in the Test Planning Guide, available upon request by contacting:

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